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How Does Mechanical Rotation and Changing Viscosity Affect Pattern Formation in Chemical Clock Reactions?

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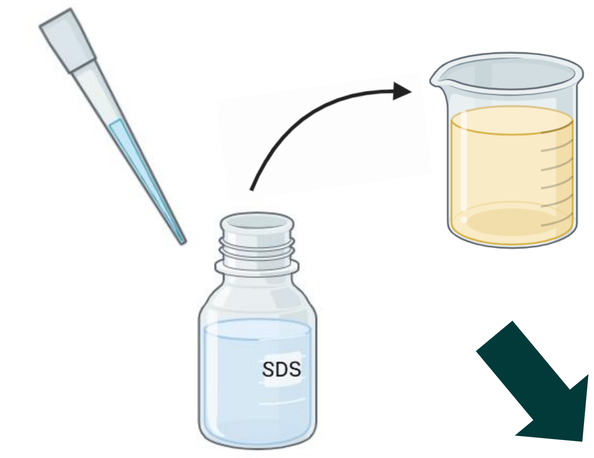
1 Background

The Belousov-Zhabotinsky (BZ) reaction is an oscillatory chemical reaction where an organic substrate is oxidised by bromate ions in the presence of a transition metal ion, producing complex wave and spiral patterns [1]. External and internal perturbations are known to alter pattern formation [2], with increasing viscosity slowing diffusion and stabilising wavefronts [3], while the influence of rotation remains largely unexplored.

The aims of this experiment were:

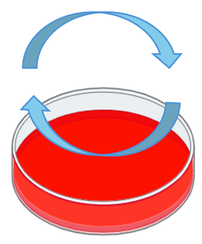
1. To determine how mechanical rotation and viscosity interact to shape wave dynamics in the BZ reaction
2. To quantify key spatiotemporal properties of the system, including oscillation period, number of wavefronts and wavelength across the perturbations

2 Methods



BZ reactions were prepared following the Winfree protocol [4] with a ferroin catalyst. Sodium dodecyl sulphate (SDS) was added to solutions at 0M, 0.1M or 0.2M concentrations. Reactions were conducted in a Petri dish mounted on a turntable at 9RPM, 18RPM, 27RPM and 36RPM respectively.





A Raspberry Pi camera was used to record timelapses at 1fps for 15 minutes. Timelapses were pre-processed by rotational alignment, grayscale conversion and ROI selection.



Dynamics were quantified using Fourier transforms to extract oscillation period, and kymographs to measure wavelength and number of wavefronts.

3 Results

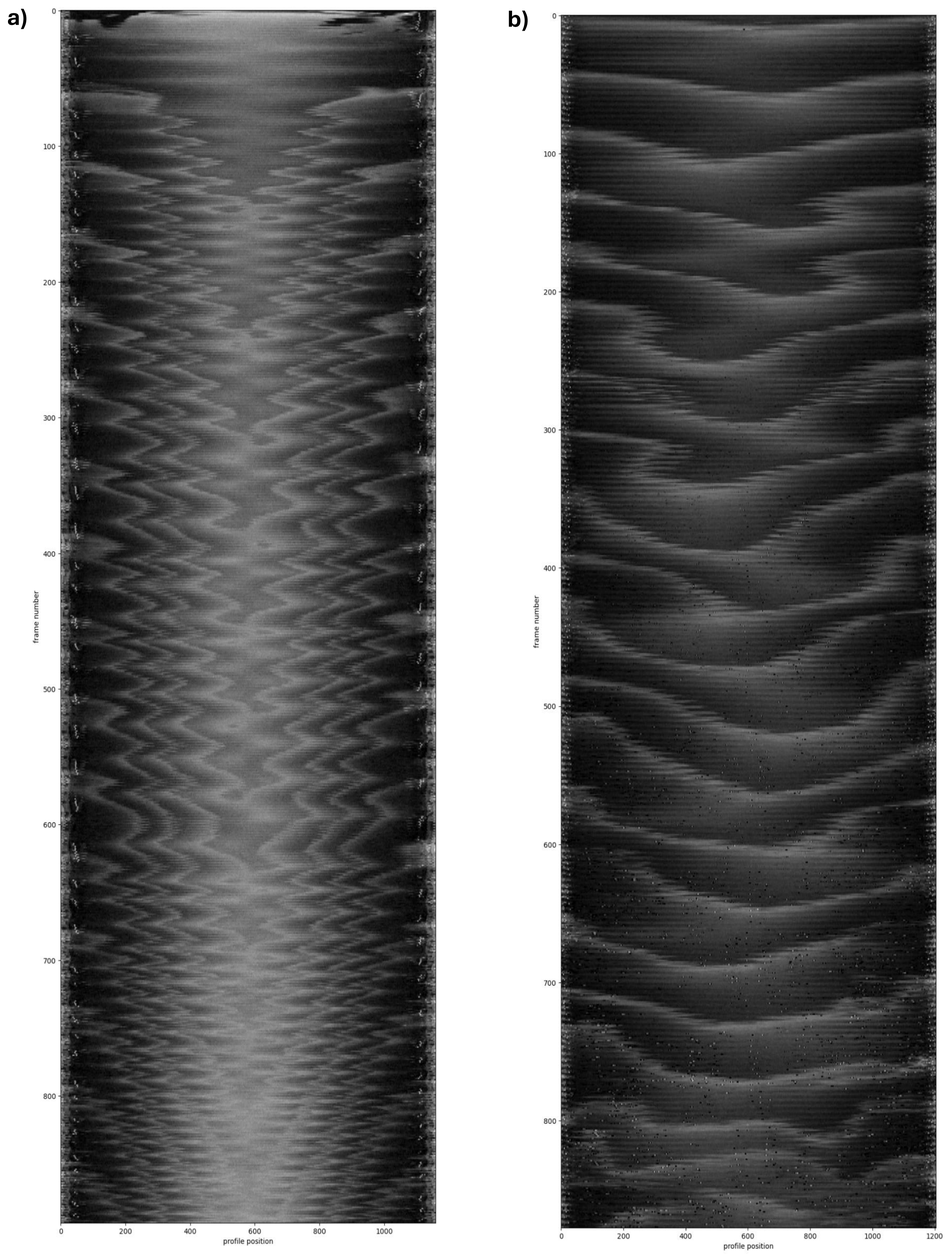


Figure 1: Kymograph plots displaying average pixel intensity across a line through the petri dish, with bright sections representing a wavefront. **a)** 36RPM with 0.1M SDS, **b)** 18RPM with 0.1M SDS.

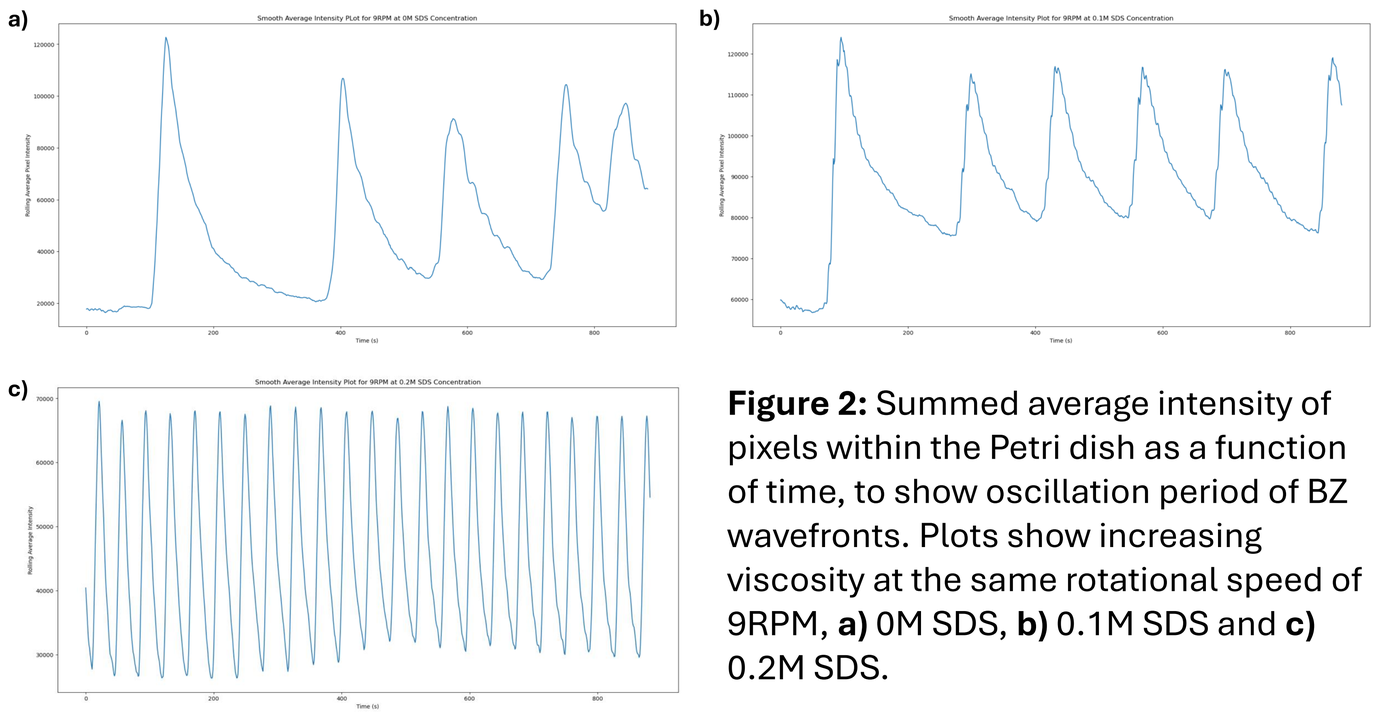


Figure 2: Summed average intensity of pixels within the Petri dish as a function of time, to show oscillation period of BZ wavefronts. Plots show increasing viscosity at the same rotational speed of 9RPM, **a)** 0M SDS, **b)** 0.1M SDS and **c)** 0.2M SDS.

4 Conclusions

- Increasing rotational speed increases the number of wavefronts formed.
- The largest number of wavefronts formed were observed at the 0.1M concentration of SDS.
- The resulting pattern formation at this concentration consisted of individual concentric circles rather than target patterns or spiral structures.
- Increasing rotational speed has little impact on oscillation period at the same SDS concentrations.
- At each rotational speed, increasing viscosity was observed to decrease oscillation period.

References:
[1] J. J. Tyson, `What Everyone Should Know About the Belousov--Zhabotinsky Reaction', in S.,A.,Levin (ed.), *Frontiers in Mathematical Biology*, Lecture Notes in Biomathematics, **100**, Springer, Berlin, Heidelberg (1994)
[2] P. Khan, S. Dutta, `Effect of concentration gradient on spiral wave dynamics in the Belousov–Zhabotinsky reaction system', Phys. Chem. Chem. Phys., **27**, 2151-2157 (2025)
[3] E. N. Zhuravleva, V. V. Pukhnachev, `On rotation of a fluid layer', Journal of Applied Mechanics and Technical Physics, **63**, 988-994, (2022)
[4] A. T. Winfree, `The Prehistory of the Belousov-Zhabotinsky Oscillator', Journal of Chemical Education, **61**, 661, (1984)
Methods icons created in BioRender https://BioRender.com

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